

The sector on a quadrant, or, a treatise containing the description and use of four several quadrants; two small ones and two great ones, each rendred many wayes, both general and particular. Each of them accomodated for dyalling; for the resolving of all proportions instrumentally; and for the ready finding the hour and azimuth universally in the equal limbe. Of great use to seamen and practioners in the mathematicks / Written by John Collins accountant philomath. Also an appendix touching reflected dyalling [by J. Lyon] From a glass placed at any reclination.

Contributors

Collins, John, 1625-1683

Lyon, John. Appendix touching reflective dialling

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1658

LYON — APPENDIX OF DIALLING



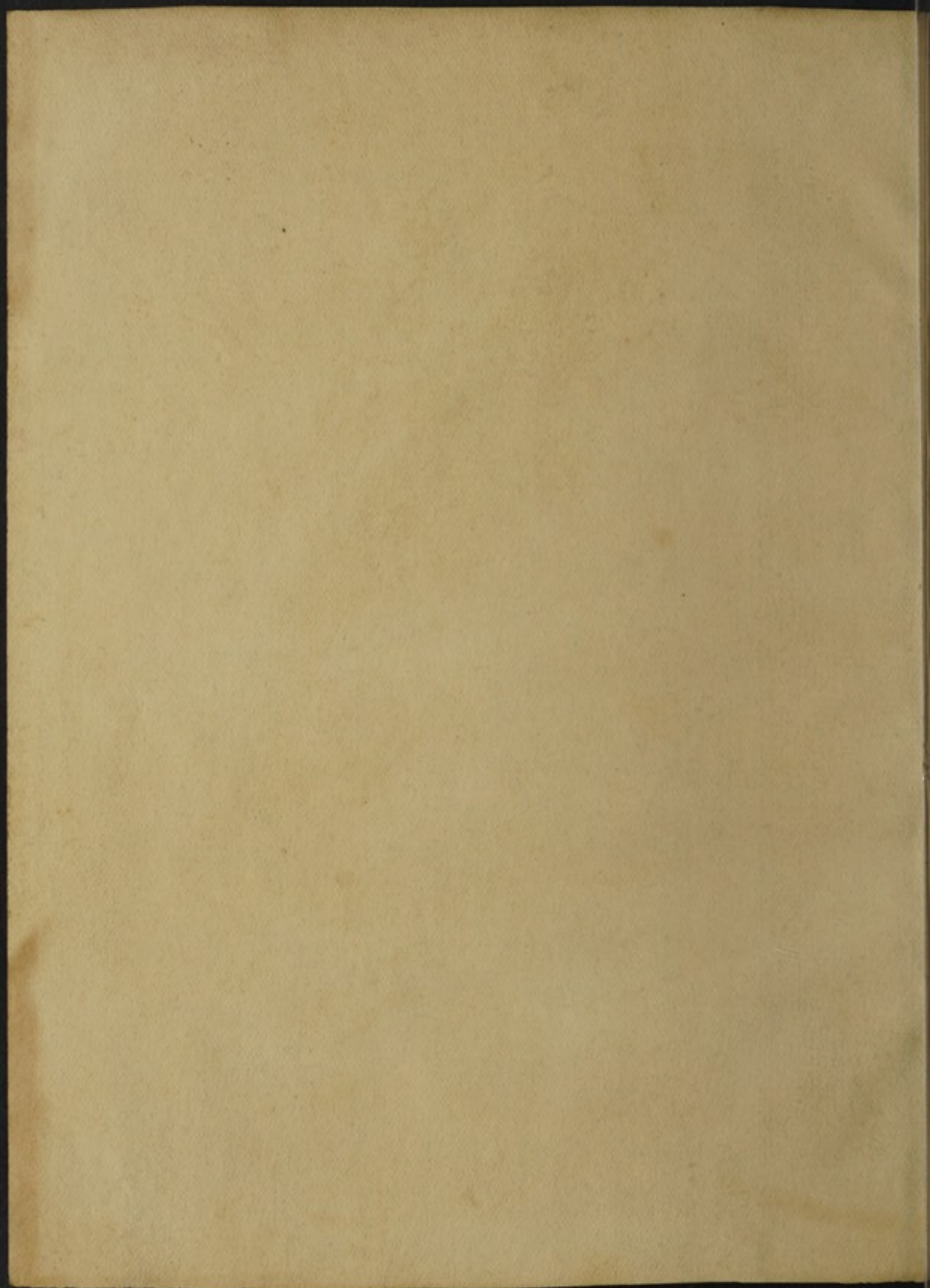




18394/B

[COLLINS, J]

Part of Collins. The sector on
a quadrant 165°9.



A N
APPENDIX

Touching
REFLECTIVE DIALLING.

By JOHN LYON:

*Professor of this, or any other part of the
Mathematicks, neer Sommerfet
House in the Strand.*



LONDON,
Printed Anno Domini, 1658.

A N
APPENDIX

Touching
REFLECTIVE DIALING.

By JOHN LYON:

Professor of this, or any other part of the
Mathematicks, near Somerset
House in the Strand.



LONDON,
Printed & sold by J. DODD, 1678.



DIRECT DIALLING

By a Hole or Nodus.

To draw a Dial under any window that the Sun shines upon by help of a thread fastened in any point of the direct Axis found in the Ceiling, and a hole in any pane of glasse, or a knob or Nodus upon any side of the window or window-post.

CONSTRUCTION.

First, draw on pastboard or other material, an Horizontal Dial for the Latitude proposed.

Then by help of the Suns Azimuth, which may be found by help of a general Quadrant, at any time, or by knowing the true hour of the day with the help of the said Horizontal Dial: and draw that true Meridian from the hole or Nodus proposed, both above on the Ceiling, and below on the walls and floor of the Room; so that if a right line were extended from the said hole or Nodus by any point in any of those lines, it would be in the meridian Circle of the World.

To finde a point in the direct Axis of the world, which will ever fall to be in the said Meridian, in which point the end of a thread is to be fastened.

First, fix the end of a thread or small silk in the center of the Hole or Nodus, and move the other end thereof up or down in the said meridian formerly drawn on the Cieling or wall, untill by applying the side of a Quadrant to that thread, it is found to be elevated equal to the Latitude of the place; so is that thread directly scituated parallel to the Axis of the world, and the point where the end of that thread toucheth the meridian either on the Cieling or wall, is that point in the direct Axis sought for, wherein fix one end of a thread, (which thread will be of present use in projecting of hour-points in any place proposed, then:

To find the Hour-points either under the window, or any other convenient place in the Room.

Place the center of the said Horizontal Dial in the Center of the Hole or Nodus; also scituate the said Dial exactly parallel to the Horizon, and the meridian of the said Dial in the meridian of the world, which (as before) may easily be done, if at that instant you know the true hour of the day.) Then take the thread whose end is fixed in a point in the direct Axis, and move it to and fro, until the said thread doth interpose between your eye, and the hour-line on the said Horizontal Dial which you intend to draw, and then keeping your eye at that scituation, make a point or mark in any place where you please, or under the window, so that the said thread or string may interpose between that point or mark so made, and your eye, as aforesaid; which said point so found will shew the true time of the day at that hour all the year long, the Sun shining thereon, so will that point, together with the said thread, serve to shew the hour, instead of an hour-line.

In like manner, the said thread fixed in the Axis may be again moved to and fro, until the said thread doth interpose between the
eye

eye and any other hour-line desired on the said Horizontal Dial and then (as before) make another point or mark in any place at pleasure, or under the said window, by projecting a point from the eye, so that the said thread also interpose between that point to be made and the eye, so will that point so found shew the true time of the day for the same hour that did the hour line on the said Horizontal Dial, which was shadowed by the said thread.

In like manner may be proceeded (by help of that thread, and the several hour-lines on the said Horizontal Dial) to finde the other hour-points which must have the same numbers set to them as have the hour-lines on the said Horizontal Dial.

Otherwise to make a Dial from a hole in any pane of glasse in a window, and to graduate the hour-lines below on the Sell, or Beam, or on the ground, that hole is supposed to be the center of the Horizontal Dial, and being true placed, the stile thereof, if supposed continued, will run into the point in the Meridian of the Cieling before found, where a thread is to be fixed; then let one extend a thread fastned in the center of the Horizontal Dial parallelly to the Horizon, over each respective hour-line, and holding it steady, let another extend the thread fastened in the Meridian, in the Cieling along by the edges of the former Horizontal thread, and so this latter thread will finde divers points on the ground, through which if hour-lines be drawn, and the Sun shine through the hole in the pane of Glasse before made, the spot of the Sun on the ground shall shew the time of the day.

For the points that will be thus found on the Beam or Transome, the thread fixed in the Cieling, or instead of it a piece of tape there fixed must be moved so up and down, that the spot of the Sun may shine upon it, and being extended to the Transome or Beam graduated with the hour-lines, as before directed, it there shews the time of the day. Here note, that it will be convenient to have that pane of Glasse darkened through which that spot is to shine.

In like manner may a Dial be made from a nail head, a knot in a string tied any where a crosse, or from any point driven into the

bar.

bar of a window, and the hour-lines graduated upon the Transome or board underneath.

To make a Reflected Dial on the Ceiling of the Room is only the contrary of this, by supposing the Horizontal Dial with its stile to be turned downwards, and run into the true meridian on the ground, where the thread is to be fixed, and to be extended along by the former Horizontal thread (held over the respective hours as before) upward, to find divers points in the Cieling, as shall afterwards be shewed.

Of Dials to stand in the Weather.

These may be also made by help of an Horizontal Dial.

DRive two nails or pins into the wall, on which the edge of a Board of comperent breadth may rest, then to hold up the other side of the Board, drive two hooks into the wall above, whereto with cord or line the outside of the Board may be sustained, and this Board being Horizontal, place the Horizontal Dial its Meridian-line in the true Meridian of the world. If a Plain look towards the South, the stile of the Horizontal Dial continued by a thread from the center will run into the Plain, which note to be the center of the new Dial, as also that line is the new stile, which must be supported with staves, when you fix it up.

By a thread from the center laid over every hour-line on the Horizontal Dial, cross the Horizontal line of the Plain, which note with the same hours the Horizontal Dial hath.

The hour-lines on the Plain are to be drawn from the center before found through those points, and to cut off by the Dial, or continued at pleasure.

If the Center of the Dial be assigned before you begin the work, in such Cases you may remove the Horizontal Dial up and down, keeping it still to the true position or hour, till you finde the Axis or stile run into the Center.

But

Refracted Dials.

But if the Plain look into the East or West, then possibly the Axis of the Horizontal Dial will not meet with the Plain: in such Cases you must fix a board so, that it may receive the Axis, (the board being perpendicular to the Plain) this stile or Axis is to be fastened to the Plain by two Rests, the hour-lines may be drawn by the eye, or shadowed out by a Light: Bring the thread that represents the Axis or stile into any hour-point (on the Horizontal Dial) by your eye or shadow; at the same time the thread or shadow making marks on the Plain, shews where the hour-lines are to passe.

After the same manner any hour-line is to be drawn over any irregular or crooked Plain. Further observe, that any point in the middle, or neer the end of the stile will as well shew the hour of the Day, as the whole stile.

Of Refracted Dials.

IF you stick up a pin or stick, or assign any point in any concave Boul or Dish, to shew the hour, and make that the center of the Horizontal Dial, assigning the meridian-line on the edges of the Boul, point out the rest of the hour-lines also on the edges of the Boul, and taking away the Horizontal Dial, elevate a string or thread from the end of the said pin fastned thereto over the Meridian-line equal to the Elevation of the Pole or the Latitude of the place; then with a candle, or if you bring the thread to shade upon any hour-point formerly marked out on the edges of the Boul, at the same time the shade in the Boul is the hour line.

And if the Boul be full of water, or any other liquor, you may draw the hour-lines, which will never shew the true hour, unlesse filled with the said Liquor again.

Re-



Reflected Dialling.

To draw a Reflected Dial on any Plain or Plains, be they never so Gibous, and Concave, or Convex, or any irregularity whatsoever, the Glasse being fixed at any Reclination at pleasure, (provided it may cast its Reflex upon the places proposed.) Together with all other necessary lines or furniture thereon, viz. the Parallels of Declination, the Azimuth lines, the Parallels of Altitude (or proportions of Shadows) the Planetary Hour-lines, and the Cuspis of those Houses which are above the Horizon, &c.

1. *If the Glasse be placed Horizontal upon the Transome of a window, or other convenient place :*

How upon the Wall or Cieling whereon that Glasse doth reflect to draw the Hour-lines thereon, although it be never so irregular, or in any form whatsoever.

CONSTRUCTIO.

First, draw on Pastboard or other Material an Horizontal Dial for the Latitude proposed.

Then by help of the Azimuth, or at the time when the Sun is in the Meridian; or by knowing the true hour of Day, whereby may be drawn several lines on the Cieling, Floor, and Walls of the Room: so as in respect of the center of the Glasse they may be in the true Meridian-circle of the World: For if right lines were extended from the center of the said Glasse by any point, though elevated in any of those lines so drawn, it would be directly in the Meridian Circle of the World.

Now

Reflected Dialling from any Horizontal Glasse. 7

Now all Reflective Dialling is performed from that principle in *Opticks*, which is, *That the angle of Incidence is equal to the angle of Reflection.* And as any direct Dial may be made by help of a point found in the direct Axis, so may any Reflected Dial be also made by help of any point found in the Reflected Axis.

And in regard the reflected Axis for the most part will fall above the Horizon of the Glasse without the window, so that no point there can be fixed, therefore a point must be found in the said Reflected Axis continued below the Horizontal of the said Glasse, until it touch the ground or floor of the Room in some part of the Meridian formerly drawn, which point will be the point in the reversed Axis desired, and may be found, as followeth.

One end of the thread, being fixed at or in the center of the said Glasse, move the other end thereof in the meridian formerly drawn below the said Glasse, until the said reversed Axis be depressed below the Horizon, as the direct Axis was elevated above the Horizon, which may be done by applying the side or edge of a Quadrant to the said thread, and moving the end thereof to and fro in the said meridian, until the thread with a plummet cut the same degree as the Pole is above the Horizontal Glasse, and then that point where the end of the thread toucheth the Meridian either on the floor or wall of the room, is the point in the reflected reversed Axis sought for.

Now if the Reversed Axis cannot be drawn from the Glasse by reason of the jetting of the window or other impediment, that point in the reverse Axis may be found by a line parallel thereto, by fixing one end of it on the Glasse, and the other end in the meridian, so as that it may be parallel to the floor or wall in which the reversed Axis-point will fall, and finde the Axis point from that other end of the lath: so if the same Distance be set from that point backward in the Meridian on the floor, as is the Lath, the point will be found in the Reversed Axis desired.

Thus having found a point in the reflected reversed Axis; it is not hard, by help whereof and the Horizontal Dial, to draw the reflected hour-lines on any Cieling or Wall, be it never so concave or convex.

K

To

2 *Reflected Dialling from any Horizontal Glasse.*

To do which : First note, that all straight lines in any projection on any Plain, do always represent great Circles in the Sphere, such are all the hour-lines.

Place the center of this Horizontal Dial in the center of the Glasse, the hour-lines of the said Dial being horizontal, and the Meridian of the said Dial in the Meridian of the world, which may be done by plumb lines let fall from the meridian on the Cieling : Then fix the end of a thread or silk in the said center of the Dial or Glasse, and draw it directly over any hour-line on the Dial which you intend to draw, and at the further side of the room, and there let one hold or fasten that thread with a small nail.

Then in the point formerly found on the reversed Axis on the floor, fix another thread there (as formerly was done in the center of the Dial) then take that thread, and make it just touch the thread (on the hour-line of the Horizontal Dial extended) in any point thereof, it matters not whereabouts, and mark where the end of that thread toucheth the wall or Cieling, and there make some mark or point.

Then again move the same thread higher or lower at pleasure, till it, as formerly touch the said same hour thread, and mark again whereabouts on the wall or Cieling, the end of the said thread also toucheth. In like manner may be found more points at pleasure, but any two will be sufficient for the projecting or drawing any hour-line on any plain, how irregular soever. For if you move a thread, and also your eye to and fro, until you bring the said thread directly between your eye and the points formerly found, you may project thereby as many points as you please at every angle of the Wall or Cieling, whereby the reflected hour-line may be exactly drawn.

Again, in like manner remove the said thread fastned in the center of the Horizontal Dial, (which also is the center of the Glasse) on any other hour-line desired to be drawn, and as before fasten the other end of the thread, by a small nail, or otherwise at the further side of the room, but so that the said thread may lie just on the hour-line proposed to be drawn on the Horizontal.

Reflected Dialling from any Horizontal Glasse. 9

zontal Dial. Then (as before) take the thread fastened in the point on the reflected Axis, and bring it to touch the thread of the hour-line in any part thereof, and mark where the end of that thread toucheth the said Wall or Cieling. Then again (as before) move the said thread so, as that it only touch the said thread of the hour-line in any other part thereof, and also mark where the end of that thread toucheth the said Wall or Cieling: So is there found two points on the Wall or Cieling, being in the reflected hour-line desired, by help of which two points the whole hour-line may be drawn; for if (as before) a thread be so scituated, that it may interpose between the eye and the said two points found, you may make many points at pleasure, whereunto the said thread may also interpose, which for more conveniency may be made at every angle or bending of the Wall or Cieling, be they never so many: So that if lines be drawn from point to point, that said reflected hour-line will be also exactly drawn.

In like manner may the other hour-lines be drawn so, that the Reflex or spot of the Sun from the said Horizontal Glasse scituated in the said window (as before) shining amongst the said reflected hour-lines drawn on the wall or Cieling, will exactly shew the hour of the day desired.

Now if lines be drawn round about the said Room, equal to the Horizon of the said Glasse, it will shew when the Sun is in or neer the Horizon.

To draw the Equator and Tropicks on any Wall or Cieling to any Horizontal reflecting Glasse.

- I *To draw the Reflected Equator or Equinoctial-line on the Wall or Cieling, which represents a great Circle.*

TAKE the thread fixed in the Center of the Glasse, and move the end thereof to and fro in the meridian line drawn on the Cieling, untill by help of a Quadrant the said thread be elevated equal to the complement of the Latitude, (which will be alwayes perpendicular to the reversed Axis) marking in the

101 *Reflected Dialling from any Horizontal Glasse.*

Meridian where the end of that thread falls, then on that point and the said meridian line on the Cieling erect a perpendicular line, which line may be continued on any plane whatsoever, and is the reflected Equinoctial line desired.

Note that all great Circles are right lines, & are alwayes drawn or projected from a right line.

2. *To draw the Tropicks. Note, that all Parallels of Declination are lesser Circles, and are Conick Sections.*

First, make or take out of some Book a Table of the Suns Altitude for each hour of the day, calculated for the place or Latitude proposed, when the Sun is in either of the Tropicks. Then take the thread fixed in the center of the Glasse, and by applying one side of a quadrant to the said thread, and moving one end of it to and fro in the hour-line proposed, elevate the said thread answerable to the Suns height in that hour, when he is in that Tropick you desire to draw, and mark where the end of that thread so elevated toucheth in that hour-line proposed. So may you in like manner finde a several point in each hour-line for the Suns height in that Tropick, whereby a line may be drawn on the Wall or Cieling from point to point formerly made in the said hour-lines, which the Tropick desired.

In like manner may any parallel of Declination be drawn: If there be first calculated a Table of the Suns altitude at all hours of the day, when the Sun hath any Declination proposed, whereby may be drawn either the Parallels of the Suns place, or the parallels of the length of the day.

To draw the parallels of Declination to any Reflected Glasse most easily, by help of a Trigon first made on past board or other material.

Fix the Trigon to the reflected reversed Axis, so that the center of the Trigon may be in the center of the Glasse, then will the Equinoctial on the Trigon be perpendicular to the said Axis: then take the thread fixed in the center of the Glasse, and lay it along

along either of the Tropicks or other parallels of Declination required, which is drawn on the said Trigon, which thread must be continued so, that the end thereof may touch any hour-line, and on that hour-line mark the point of touch, the thread being still laid on the same parallel of declination on the Trigon: in the same manner finde a point in each hour-line. Lastly, draw a line by those points so found, which will be the Tropick-line or other parall. l of declination, as the thread was laid on, on the Trigon.

To draw the Azimuth-lines on any Wall or Cieling to any Horizontal reflecting Glasse. Note that all Azimuths are great Ciroles.

First, find a vertical point, either above to the Zenith, or below to the Nadir of the Glasse (by some called a perpendicular or plumb line) and mark in what point it cuts the floor of the room, which point I call the reflected vertical point, wherein the end of a thread is to be fixed: For by a point found in the reflected Axis of the Horizon the Azimuths may be drawn, as by a point found in the reflected Axis of the Equinoctial the hour-lines may be drawn.

Then on pastboard or other material draw the points of the Compasse or other degrees, and fix the center thereof in the center of the Glasse, and the meridian thereof in the meridian of the world, as was shewn in drawing the hour-lines, being careful to place it horizontal.

Then take the thread fixed in the place of the glasse, and draw it over any Azimuth, which is desired to be drawn, and at the further side of the Room fasten that thread with a small nail as it was in drawing the reflected hour-lines: Then take the thread whose end is fastened in the said reflect vertical point, and bring that thread so as just to touch the said horizontal thread, and augment it, until the end thereof touch the wall or Cieling, and there make a mark or point. In like manner, move the said thread, whose end is fastened in the said vertical point, higher or lower at

plea-

pleasure, till as formerly it touch the said horizontal thread, and mark again whereabouts the end thereof toucheth the said Wall or Cieling: Now by help of these two points found in the reflected Azimuth line, the whole Azimuth line may be drawn; for if (as before in drawing the Hour-lines) a thread be so situated, that it may interpose between the eye and the said two points, you may make many points at pleasure, to which the said thread so situated may also interpose, which may be made at every angle or bending of the wall or Cieling (as before) whereby the reflected Azimuth-line desired may be drawn. In like manner may the other reflected Azimuth lines be drawn.

Also there may be lines drawn parallel to the Horizon round about the room, by help of the thread fixed in the center of the Glasse, and a Quadrant for the elevation thereof, which will shew the Suns altitude at any appearance thereof.

Thus have I shewed the drawing of a Reflected Dial from an Horizontal Glasse, with all the usual furniture thereon, though the wall or place on which it is to be drawn be never so gibbous or irregular, or in what shape soever.

Now the Glasse may be exactly situated Horizontal, if you draw a reflected parallel for the present day, and know also the true hour, and so place the Glasse, that the spot or reflex of the Sun may fall thereon on the Cieling, for there is no way by an Instrument to do it, the Glasse is so small.

Of



Of Reclining Reflecting Glasses.

Reflected Dialling from any Reclining Glasſe.

I ſhall now ſhew how to draw any Reflected Dial, with all the Furniture (that poſſible may be) the Glaſs being ſet at any poſſible Reclination.

In the drawing of which there is principally to be conſidered,

1 *The Reflected Horizon.* | Note, the Horizon & Meri-

2 *The Reflected Meridian.* | dian are two great circles.

1 *To draw the Reflected Horizon according to the ſituation of
any reclining Glaſſe whatſoever.*

Firſt, let two pieces of nealed wire be faſtened on the window on each ſide of the ſaid Glaſſe, the ends thereof being without the room in the air, at whoſe ends let there be faſtned a thread which may be pulled ſtraight at pleaſure, by bending of the wire, then bend thoſe wires upward or downward, until the thread faſtened at the end of each wire be exactly horizontal with the center of the Glaſſe, which may be tried by a quadrant: Then I tie a ſtring or thread croſs the room, in ſuch ſort that I may from moſt part of the thread ſee the reflecting glaſs, and therein the ſaid horizontal thread without the room: Then on the ſaid thread croſs the room, I tie a ſlipping knot to move to and fro at pleaſure, which knot I move to and fro on the ſaid thread, until by looking in the ſaid Glaſſe I finde from my eye the ſaid knot and part of the horizontal thread without, all as it were in a right line, the one interpoſing the ſight of the other.

Then

Then being careful to keep the knot in that position, fasten one end of a thread in the place of the center of the reclining reflecting glasse, and bring that thread so, as just to touch the aforesaid knot, augmenting that thread, until the end thereof touch the wall or Cieling, and there make a mark or point, so is there one point found on the Wall or Cieling in the Reflected Horizon of the World. Then I begin again, and remove the position of that thread (which went overthwart the Room) either higher or lower at pleasure, still having regard that I may from the most part of the said thread see the Reflecting Glasse, and therein the same horizontal thread without the room. Then, as before, I move the said knot on the said thread to & fro, until (as before) by looking in the said Glasse I find from my eye the said knot, and part of the Horizontal thread both in one right line, the one interposing the sight of the other; and by the said knot I bring that thread, whose end is fastened in the center of the said glasse, and keeping it just to touch the said knot, I continue it, until the end thereof touch the Wall or Cieling, as before, and there I make another mark or point; so is there two points found in the said reflected Horizon on the wall or Cieling. By which said two points, if a thread (as before) be so scituated, that it may interpose between the eye and the said two points, there may be many points made to be in the same interposition of the thread, which (as before) may be made at every bending or angle of the Wall or Cieling, whereby the reflected Horizon desired may be drawn, by drawing a line from point to point round about the Room; Which will be the true reflected Horizon according to the situation of the glasse.

2 *To draw the Reflected Meridian, according to the situation of any Reclining Glasse whatsoever.*

First, take a lath or thin piece of wood of any convenient length at pleasure, as some one and an half, or two foot long, and at each end thereof make a hole, the one to hang a thread and plummet, and the other is to put a small nail therein to fasten it in some part of the window over the center of the Glasse, so that

that the thread and plummet may hang without the room: then by help of the Suns Azimuth you may draw the meridian line, (as before) as if the Glasse were horizontal, and move the lath with the thread and plummet at the end of it to and fro, until the thread and plummet be in the direct meridian of the world with the center of the Glasse. Then (as before) tie a thread crosse the room, in such sort that from or by some part of the said thread both the Reclining glasse and the thread to which the plummet is fastened may be seen at one time. Then (as before) on the said thread, which crosses the room, I tie a slipping knot, which I move to and fro on the said string, until by looking in the said Glasse I find from my eye the said knot and some part of the perpendicular thread without, all as it were in one right line, the one shadowing or interposing the sight of the other, being then very careful to keep that knot in the same position, then take the thread (whose end whereof being fastened in the said center of the Glasse) and bringing it just to touch the said knot, I augment that thread, until the end thereof touch the said wall or Cieling, and the said thread also touch the knot, as before: then in that place where the end of the said thread toucheth the wall or Cieling, I make a mark, which mark or point will be directly in the reflected meridian of the world, according to the situation of that Glasse. Then again I remove that thread (overthwart the room) on which the said knot is, either higher or lower then it formerly was at pleasure, still having regard that from some part of the said thread within, you may see both the Reclining Glasse, and the perpendicular thread without at one time; and (as before) move the said slipping knot on the said thread, until by looking in the said Reclining Glasse, you see the said knot and some part of the perpendicular thread without in one right line, so as the one shadows or hinders the sight of the other, (as before) which knot then must not be removed from its situation, then take that thread (whose end is fastened in the Glasse) and bring it to touch that knot, the end of the said thread being continued to touch the wall or Cieling: so is that point of touch on the Cieling another

point found in the Reflected Meridian of the world. So is there two points found in the said Reflected Meridian, on the wall or Cieling; by which, if a thread (as before) be so situated, that it may interpose between the eye and the said two points, many points thereby in the said reflected Meridian may be made at every bending or angle of the wall or Cieling, whereby the Reflected meridian desired may be drawn, by drawing a line from point to point obliquely in the Room, which will be the true Reflected Meridian of the world, according to the situation of that Glasse.

Now this Reflected Horizon and Meridian being first drawn, they will be of great use in drawing the Hour-lines, together with all the furniture that possibly can be drawn on any Diall.

To draw the Reflected Hour-lines to any Reclining Glasse on any plane whatsoever, that the Sun will be reflected on: By help of an ordinary Horizontal Dial for that Latitude.

First, extend several threads from the center of the Glasse to the extremity of the Reflected Horizon in the Room (which for more conveniency and use may be the several hour-lines, and may also serve as a bed to situate the Horizontal Diall on the Reflected Horizon) having regard to situate the center of the Dial on the center of the Glasse, and the Meridian of that Dial on the Reflected Meridian of the World: Then to finde the point in the Reflected reversed Axis on the floor of the Room; Take a thread, one end thereof being fastened in the center of the Glasse, and move the other end thereof to and fro in the reflected meridian under the Reflected Horizon, until by help of a Quadrant the said thread is found to be depressed under the reflected Horizon, equal to the latitude of the place, and where the end of the

the said thread intersects or meets the Reflected Meridian either on the floor or wall, that point is the reflected reversed Axis, as was required. In which point fasten one end of a thread, which thread will be of great use in drawing the reflected hour-lines on any wall or Cieling whatsoever. Now if this thread, whose end is fastened in a point on the reflected reversed Axis, be taken and brought to touch any part of any one of the threads of the hour-lines (produced to and fastened in the reflected Horizon) the said thread being continued so, as the end thereof may touch the wall or Cieling, and also any part of the said thread touch the hour-line or thread proposed; that point on the wall or Cieling is in the reflected hour-line desired to be drawn: Also the other point in the same reflected hour-line may be found; If the said thread, whose end is fastened in the Reflected Axis, be brought to touch some other part of the same hour-thread proposed; so that when (as before) the end of the said thread toucheth the wall or Cieling, some part of that thread may also touch the hour-line desired, which point of touch on the wall or Cieling, is also another point in the said reflected hour-line desired. By which two points so found (as before) the reflected hour-line may be drawn by a thread, projecting by those points from the eye, as it was formerly directed in drawing the reflected hour-lines to an Horizontal Glasse.

To draw the Reflected Equinoctial line, and also the Tropicks on any wall or Cieling, to any Reclining Reflecting glasse.

I *To draw the reflected Equinoctial line on the Wall or Cieling.*

TAKE that thread, whose end is fastened in the center of the reclining glasse, and move the other end thereof to and fro in the said Reflected meridian formerly drawn, until (by help of a quadrant) the said thread is elevated above the reflected Horizon formerly drawn, equal to the Complement of the Latitude,

(which as before will be alwayes perpendicular to the reversed Axis) and make a point in the said reflected meridian, where the end of the said thread toucheth; then on that point and the said reflected meridian on the Cieling, raise a perpendicular line, which is the Reflected Equinoctial line desired.

2. To draw the reflected Tropicks, or other Parallels of Declination.

First, (as before) make or take out of some Book a Table of the Suns Altitude for each hour of the day, calculated for the place or Latitude proposed, when the Sun is in either of the Tropicks, or other parallel of Declination: then take that thread, whose end is fastened in the center of the Glasse, move the other end thereof to and fro in the hour-line proposed, until by applying one side of a quadrant to the said thread you find the said thread elevated above the reflected Horizon answerable to the Suns height in that hour proposed, when he is in that Tropick or degree of Declination proposed. Which altitude required will be found in the foresaid Table for that end calculated, which said thread being of the elevation above the reflected Horizon, as the said Table directeth: then mark where the end of the thread (so elevated) toucheth the Wall or Cieling in that hour-line: so is one point found in the reflected parallel of Declination desired to be drawn. In like manner, find in the said Table in the same parallel or degree of declination what altitude the Sun hath at the next hour, and elevate the said thread, whose end is fastened in the center of the Glasse, equal to the Suns altitude in that hour above the said reflected Horizon, by help of the said Quadrant, and where the other end of the said thread falleth in the hour-line proposed, make another mark or point. And so in like manner make the points (belonging to that parallel of Declination) in the remaining hour-lines, according to the severall Altitudes found in the said Table of Altitudes: Then drawing by hand a line to passe through those severall points so found, as before, which line is the reflected

ed parallel of the Suns declination desired. In like manner may be drawn all or any other parallel of Declination, which may have respect to the Suns place, or the length of the day, as shall be desired.

Or,

To draw the said reflected Tropicks, or other parallels of Declination, without any Tables calculated, only, by help of a Trigon first made on pastboard or other material.

Note that all Parallels are lesser Circles.

FIRST (as formerly is shewd in drawing the parallels of Declination to a Reflecting Horizontal Glasse) fasten the Trigon on the reflected reversed Axis, so that the center of the Trigon may be in the center of the Glasse, then also will the Equinoctial on the Trigon be perpendicular to the said reflected reversed Axis: then take the thread fixed in the center of the said Glasse, (which is also in the center of the Trigon) and lay it upon that parallel of Declination, drawn on the said Trigon, whose reflected parallel is required to be drawn on the plane or Cieling: then move the Trigon, the thread lying on the said parallel, until the end of the said thread touch any hour-line on the said wall or Cieling, in which point of touch on that hour-line make a mark, so will that point be in the reflected parallel of Declination desired. In like manner, move the said Trigon, still keeping the thread on the same parallel, until the end of that thread touch another hour-line on the said plane or Cieling, and there also make another mark. And so in like manner find a point in each hour-line through which that reflected parallel must passe; then drawing a line to passe through those several points on the said plane or Cieling, which line is the reflected parallel of the Suns Declination desired.

In like manner may be drawn any other reflected parallel of Declination required.

To draw the reflected Azimuth-lines to any reclining Glasse, on any plane whatsoever that the Sun-beams will be reflected on. Here note that Azimuths are great Circles.

First, know that the reflected vertical point in the Axis of the Reflected Horizon, will alwayes be found in the reflected meridian. And look how many degrees the reflected Horizon differs from the direct Horizon, so many must the reflected Axis of the Horizon differ from the direct Axis of the Horizon: Hence the reflected vertical point, whereby the reflected Azimuth-lines are drawn, may be thus found.

Take that thread whose end is fixed in the center of the Glasse, and move the other end thereof to & fro in the reflected meridian, until by applying one side of a quadrant thereto, you find the said thread depressed just 90 degrees, or perpendicular under the reflected Horizon; then make a mark or point where the other end of the said thread toucheth the said reflected Meridian on the Wall, Ground, or Floor of the Room, which point so found is the reflected vertical point desired, in which point fasten one end of a thread:

Then on pastboard or other material draw the points of the Compasse or other degrees, placing the center thereof in the center of the Glasse, and the meridian thereof in the reflected meridian of the world, which said pastboard must be also situated in the reflected Horizon just as the Horizontal Dial was formerly directed to be situated for drawing the reflected hour-lines: And as the threads from the center fastened in the reflected Horizon were also the hour-lines on the Horizontal Diall, whereby the reflected hour-lines were drawn. So now the threads from the center fastened in the Reflected Horizon may be the Horizontal Azimuth lines, whereby the reflected Azimuth-lines may be drawn: Or if that thread which fastned in the center of the glass be drawn exactly over any Azimuth-line, the end whereof being

being fastened by a nail or other means in the reflected Horizon on the other side of the Room, there may several points be found in the wall or Cieling, through which the reflected Azimuth line must passe, as followeth :

Take that thread, one end of which is fastened in the said vertical point, and bring it just to touch the Azimuth thread formerly fastened, and continue it until the end thereof touch the wall or Cieling, (and also the thread it self touch the said Azimuth it self, as before) in which point of touch on the wall or Cieling make a mark, through which point that reflected Azimuth-line must passe. Then move the said string fastened in the said vertical point, so that it may just touch the said thread again, but in another place : then as before continue that thread, untill the end thereof touch the wall or Cieling again, as before, and there make another mark, through which the said reflected Azimuth line must also passe ; In like manner may more points be found for your further guide, in drawing that Azimuth-line. But two points being found will be sufficient.

To draw any reflected line by any two points given over any plane whatsoever, without projecting by the eye.

Fasten two threads in the place of the center of the said reclining Glasse, drawing the said threads straight, fastening each of the other ends in the two reflected Azimuth-points formerly found on the wall or Cieling. Then situate a thread cross or thwart the room, so as it may crosse those other threads from the center, neer at right angles, and also just touch both of them in that situation. By which said thread crosse the room may any number of points in the said reflected Azimuth-line to be drawn, be found at pleasure : For if the end of another thread be also fastened in the center of the said Glasse, making the other end thereof to touch the wall or Cieling, but so that it may also just touch the said thread, which is fastened crosse the room, which
point

point of touch on the said wall or Cieling is another point in the said reflected Azimuth line required to be drawn. In like manner may more points be found at every angle or bending of the wall or Cieling for the exacter drawing the reflected Azimuth line required, which doth find points, whereby is drawn the same reflected Azimuth line (or other lines) as was formerly done by a thread so situated, that it may interpose between the eye and any two points assigned on the wall or Cieling.

In like manner, if the thread fastened on the further side of the room were removed on another Azimuth line on the said pastboard, and then fasten it again on the further side of the room (as before) you may by help of the said thread fastened in the said vertical point find several points on the wall or Cieling, through which that Azimuth-line will passe; So may you either by this or the former way draw what Azimuth lines you please, either in points of the Mariners Compasse or degrees, as you please, by drawing it first on pastboard, as before is directed.

And note generally, that such relation the point found on the floor or ground in the reflected reversed Axis, hath to the hour-lines drawn on the Horizontal Dial, in drawing the reflected hour-lines; The same hath the Reflected vertical point found on the floor or ground, to the Azimuths drawn on the pastboard in drawing the reflected Azimuth-lines.

To draw the reflected parallels of the Suns altitude, or proportions of shadows to any reclining Glasse on any Plane whatsoever, that the Sun-beams will be reflected on.

Here note, that parallels of Altitude are lesser Circles, therefore are not represented by a right line.

First, know generally that what respect the parallels of Declination have to the hour-lines, such have the parallels of Altitude to the Azimuths.

For if one end of a thread be fastened in the place of the center

ter of the reclining Glasse, and the other end moved to and fro in any reflected Azimuth line, until the said thread be elevated any number of degrees proposed above the reflected Horizon (the Elevation of which thread being found, by applying a Quadrant thereto, and making a mark or point where the end of the said thread toucheth the said reflected Azimuth drawn on the wall or Cieling, that point so found is the point through which that Almicanter or reflected parallel of the Suns altitude must passe.

In like manner, remove the other end of the said thread fastened in the center of the Glasse to another reflected Azimuth-line, and (as before) move it higher or lower, untill by applying the edge of a quadrant to that thread, you find the said thread above the reflected Horizon the same number of degrees first proposed, and at the end of the said thread in that Reflected Azimuth-line drawn on the wall or Cieling I make another mark or point, through which the same Reflected Almicanter or parallel of Altitude must also passe: And so in like manner I find a point on each reflected Azimuth-line, through which the same parallel of Altitude must passe. Then drawing by hand a line to passe through these several points so found, as before, that line is the Reflected parallel of the Suns Altitude proposed. In like manner may be drawn all the other parallels of Altitude desired, which will shew the Suns altitude or the Proportion of any shadow to its altitude, at any appearance of the Suns reflex thereon.

To draw the Jewish or old unequal hour-lines to any Reclining Glasse on any plane whatsoever that the Sun-beams will be reflected on. Here note that the Jewish hour-lines are great Circles.

First, (by the Rules formerly given) draw two reflected parallels of Declination of $16^{\circ} 55'$, the one being neer the Summer, and the other neer the Winter-Tropick: for when the Sun hath that Declination, the day is 15 hours long in the Summer, and 9 in the winter: Then (as is formerly directed) situate

a thread just between the eye, and those three points in the said Reflected Dial, as is expressed in the insuing Table, so may you thereby draw all or any of those Jewish hour-lines desired, which will at any appearance of the spot by the reflex of the Glasse amongst those hour-lines, shew how many of the equal hours is past since Sun-rising, as was desired. Now in this Latitude of 51 deg. 30', If the parallels of the Suns declination be drawn, both when the day is 9 and 15 hours long, that is, when it is 16d. 55', any of those Jewish hour-lines will intersect the common hour-lines, either upon the hours, half hours, or quarters. And such a declination may be found, that it shall so do in any Latitude desired.

| <i>Unequal Hours.</i> | <i>15 H.M.</i> | <i>Equ. H.</i> | <i>9 H.M.</i> | <i>Unequ. hours</i> | <i>15 H.M.</i> | <i>Equ. H.</i> | <i>9 H.M.</i> |
|-----------------------|----------------|----------------|---------------|---------------------|----------------|----------------|---------------|
| 0 | 4 30 | 6 | 7 30 | | | | |
| 1 | 5 45 | 7 | 8 15 | 7 | 1 15 | 1 | 0 45 |
| 2 | 7 00 | 8 | 9 00 | 8 | 2 30 | 2 | 1 30 |
| 3 | 8 15 | 9 | 9 45 | 9 | 3 45 | 3 | 2 15 |
| 4 | 9 30 | 10 | 10 30 | 10 | 5 00 | 4 | 3 00 |
| 5 | 10 45 | 11 | 11 15 | 11 | 6 15 | 5 | 3 45 |
| 6 | 12 00 | 12 | 12 00 | 12 | 7 30 | 6 | 4 30 |

To draw the Circles of Position to any reclining Glasse on any plane whatsoever, that the Sun-beams will be reflected on.

Note that all Circles of Position are great Circles of the Sphere, and do alwayes intersect each other in that point of the Reflected meridian which toucheth the Reflected Horizon, which may be called the common intersection; which said Circles of Position are reckoned upon the Reflected Equinoctial both ways from the said meridian down to the said Horizon: The Horizon Eastward being the Cuspis of the first House, and the Horizon Westward being the Cuspis of the seventh House; and the Reflected meridian the cuspis of the tenth House. So that those

those Meridian-planes, whose Reclination is 60 degrees Westwards, (being measured from the meridian in the Equinoctial) lies in the Cuspis of the eighth House, and 30 degr. Westward lies in the Cuspis of the ninth house, and 30 deg. Eastward in the Cuspis of the eleventh House, and 60 deg. Eastward in the Cuspis of the twelfth House: which are all the Houses above the Horizon.

Now to draw any Circle of Position, or the Cuspis of any House on any Cieling or wall to any reclining Glasse is done as followeth:

First, fasten a thread, in such sort, within the Room, as that it may interpose between the eye and the said common point of intersection on the wall or Cieling, and also between that point where the reflected hour-line of 4 (being 60 deg. Westward from the said Meridian) intersects the reflected Equinoctial also on the Cieling, whereby points may be made at every bending or angle of the wall or Cieling, to which the thread so situated may also interpose, by which points the Reflected Cuspis of the eighth House may be drawn. In like manner may the Cuspis of any other House above the Horizon, as the 9th, or 10th, which is the Meridian (or *Medium Caeli*) or 11th, or 12th, be drawn also. For if (as before) the said thread be again so fastened within the Room, as that it may also interpose between the eye and the said common point of intersection, and also those points where the reflected hour-line of 2 (being 30 deg. Westward from the said meridian) do cut the reflected Equinoctial, whereby may be drawn the reflected Cuspis of the ninth House. Or where the Reflected hour-line of 10 (being also 30 deg. Eastward from the meridian) do also cut the said reflected Equinoctial, whereby may be drawn the Cuspis of the 11th House. Or where the reflected hour-line of 8 (being 60 deg. Eastward from the meridian) do also cut the said reflected Equinoctial, whereby may be drawn the Cuspis of the 12th House. The Horizon alwayes being the Cuspis of the first and seventh Houses, and the meridian the Cuspis of the

the tenth house or *Medium Cœli*: wherein generally it is to be noted, That in all planes which cut the common Intersection of the meridian and Horizon, (as doth the Horizontal, and also all meridian planes both Direct and Reclining) these Circles of Position are all parallel to the meridian, and therefore parallel each to other. For look what respect the hour-lines in all Direct or Reclining Polar Planes, or Direct meridian Planes have to the Axis of the World: Such respect have the Circles of Position, in all Horizontal, or Direct meridian or Reclining meridian Planes, to the Axis of the Prime vertical: For as the hour-lines in the first are all parallel to the Axis of the Equinoctial, in whose Poles they meet: So the Circles of Position in the second are all parallel to the Axis of the Prime Vertical, in whose Poles they also meet.

The reason why Glasses reflect a double Spot, is because they are polisht on both sides, which may be remedied with a Pumex-stone. Those that desire to read more of this Subject may see what is written by Kircher, in primitiis Gnomicæ Catoptricæ, and since him by Magnan and others,

V A L E.

F I N I S.

